Research Order #2
Phase I - Progress Report #5

7 September 1954

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OBJECTIVE:

To develop a transistorized receiver in the frequency range 5-7 mc, with a sensitivity of 30-60 uv/m and total input power of 60 milliwatts or less.

DATA - GENERAL:

The use of junction transistors as local oscillators and mixers was investigated, suitable circuits were developed, and a breadboard layout of a complete receiver was constructed.

DATA - DETAILED:

Various types of oscillator circuits were tested using both crystal and LC resonant elements. Of the several transistors immediately available, a [redacted] type CK721 was chosen for the first investigations. No limitation 25X1
was placed on input power since the initial aim was to determine the maximum stable operating frequency. Using a Colpitts circuit (Figure 5) and a 45-volt center tapped battery, three different CK721 transistors were tried with the following results:

Transistor A	2.95 mc/s
Transistor B	2.2 mc/s
Transistor C	2.0 mc/s.

Since 45 volts is higher than would be desirable for equipment of this nature, further investigations were made but with a battery voltage limited to 6 volts. Again a Colpitts circuit was employed, yielding a maximum frequency of 1.78 mc/s. Several other circuits similar to those used in broadcast transistor receivers developed by [redacted] 25X1
[redacted] were also tried; however the maximum frequency obtained was 25X1
only 1.2 mc/s.

During this period we were able to obtain two [redacted] CK762 transistors. 25X1
These were used in a Colpitts circuit similar to that used with the CK721. This combination resulted in stable operation of frequencies as high as 12.8 mc/s. The crystal oscillator circuit shown in Figure 13 in combination with a CK762 gave good results at 6.4 mc/s.

Simultaneous with the above, work was done with regard to the use of transistors as mixers and as detectors.

Information from outside sources claimed greater conversion gain at broadcast frequencies than at intermediate frequencies with the result that double conversion was considered. Tests made using a CK762 as a mixer resulted in slightly less gain as a mixer than as an amplifier. These tests were later confirmed by outside sources working on broadcast receiver development. As a result the double conversion was abandoned.

To keep oscillator radiation through the antenna to a minimum it was decided to inject the oscillator on any element other than the input.

A Tetrode type RDX302 was tried as an i-f amplifier and as a mixer. The gain as an amplifier exceeded that of the CK762 by greater than 6 db, feeding signal into the emitter as recommended by the manufacturer. However, using oscillator injection on either base resulted in 10 db less conversion gain. Conversion gain approximating that of the CK762 could be obtained by injecting both signal and local oscillator into the emitter. Since this was not an improvement and would result in increased oscillator radiation, the tetrode was abandoned as a mixer at these frequencies. All mixer tests were conducted at approximately 5.45 mc.

Base injection of the oscillator was chosen since the necessary oscillator voltage is approximately 1/3 that of emitter injection for similar conversion gains. The final circuitry resulted in conversion gains of 15 db to 18 db.

To achieve an input frequency range of 5-7 mc, advantage is taken of the oscillator being above or below the desired signal, and the oscillator range is now 4.755 mc to 6.745 mc enabling reception of 4.3-7.2 mc.

The second detector circuits shown in Figure A and Figure B were investigated with regard to output, current requirements, simplicity and transistor interchangeability. In all cases the input signal was 455 kc/s with 1000 cps - 30% modulation.

The secondary of the output transformer was loaded with a 1000-ohm resistor to simulate the following stage, and the output measurements taken across this load.

Using a CK721 connected grounded base (Figure A), approximately 4 times the output was obtained as compared to the grounded emitter connection shown in Figure B. The input signal was the same in both cases. The current requirements for the grounded base connection however, was about 4 times that of the grounded emitter connection. The grounded base connection also requires a greater number of components and a tapped power source.

When changing transistors, R_1 had to be readjusted to obtain maximum power output. The grounded emitter connection exhibited good stability of output and current requirements with various transistors. The circuits shown in Figures A and B were both tested with a CK760 and a CK762 transistor. The circuit of Figure B showed the greatest improvement of the two, with no appreciable increase in current requirements. Utilizing the above results, an essentially complete receiver was constructed and tested. The oscillator circuit was chosen since it resulted in constant output over a wide range of frequencies. The circuit of Figure B was selected for the detector because of its simplicity, low power requirements, and stable characteristics without the use of selected transistors.

[illegible]

The receiver is a superheterodyne, tunable from 5 mc/s to 7 mc/s, with a mixer, local oscillator, two stage i-f amplifier at 455 kc, second detector and one audio stage. Six transistors are used as follows:

Noise Figure of Receiver

Mixer		Type 760	25X1
Oscillator		Type 762	
I-f Amplifiers		Type 760	
Power Detector		Type 762	
Audio		Type 721	

I-f stage gains of 33 db were obtained with commercially available i-f transformers (Automatic Mfg. Corp. #EXO 3015). Mixer conversion gain is approximately 15 db. Audio output with 5-volt supply is approximately 0.8 mw. Total current drain from 5-volt supply is 2.1 ma.

Sensitivity measured at mixer input (base - 50-ohm source) is 4 uv for rated audio output (signal modulated 30% at 1000 ~). With an 8-inch ferrite loopstick resonant at 5 mc, a sensitivity of 30 mv/m was measured.

Limited field tests of this receiver with the loop transmitter described in Report #4 gave adequate signal at 0.5 mile range, corresponding to a field strength of 11-15 uv/m.

Automatic gain control was tried on this receiver, but could not be developed satisfactorily in time for this report. A simple r-f gain control is used in the emitter of the 1st i-f amplifier, giving about 40 db range.

Considerable work was done with audio type junction transistors at 100 kc/s as self-excited and crystal controlled oscillators in an attempt to determine maximum power output and efficiency without a frequency limitation. Various combinations of single ended and push-pull oscillators, and push-pull, class C final amplifiers were tried.

Best results were obtained with a single ended self-excited oscillator using a CK721 with a 6-volt supply. Power output was 50 mw at 67% efficiency.

Somewhat similar performance has been obtained with type CK762 transistors, at 5 mc to date. Work is continuing to determine optimum circuitry. It has been suggested two type CK762 transistors in a push-pull, class C oscillator are capable of 250 mw input and 60% efficiency at 5 mc.

CONCLUSIONS:

It is felt that a satisfactory basic receiver design has been achieved. The addition of AGC and stabilization for temperature and battery voltage remain to be done.

Since the receiver performance is better than expected and can be further improved, the transmitter problem is simplified to the extent that the required carrier power is much reduced, and can be obtained from existing transistors, with the powerful advantages of common battery operation.

WORK PROGRAM FOR NEXT INTERVAL:

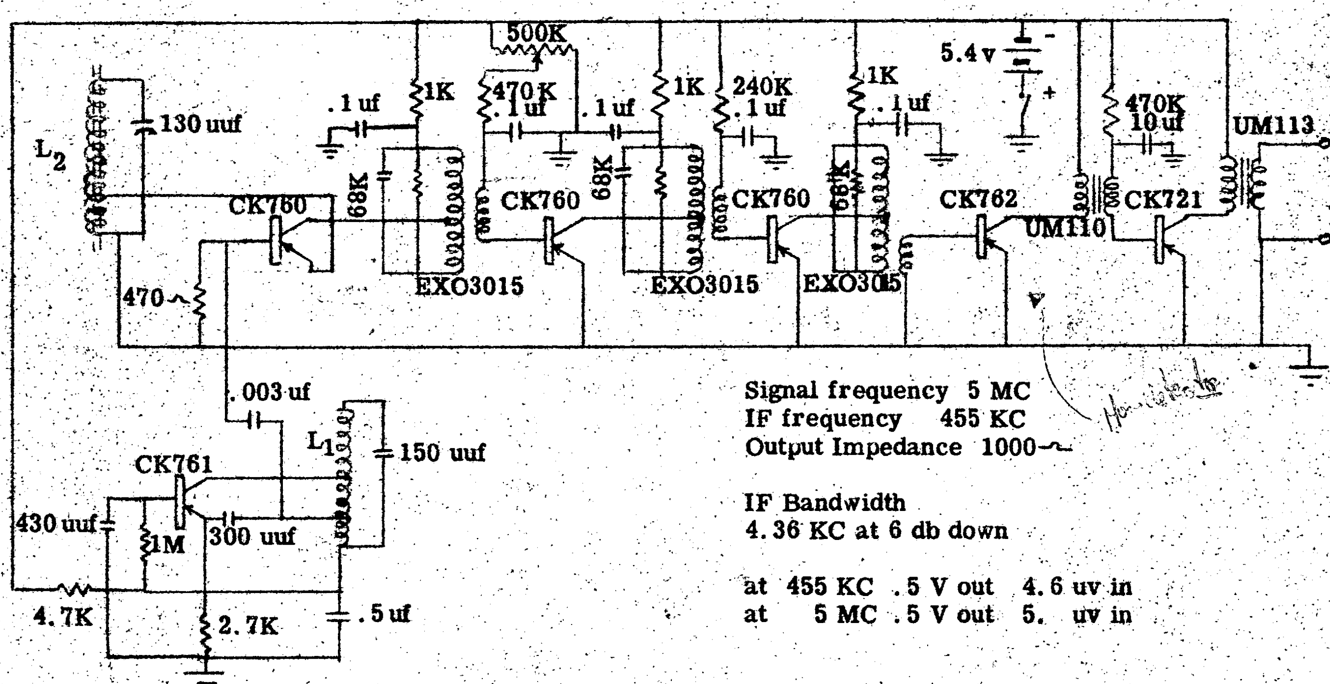
Completion of receiver circuitry, determination of transistor limitations as r-f power generators at 5 mc, field comparisons of Ferrite loop-stick antennas and air loops on existing receiver are part of the work program for the next interval.

25X1

Report prepared by

Report approved by

[redacted]



Signal frequency 5 MC
IF frequency 455 KC
Output Impedance 1000 Ω

IF Bandwidth
4. 36 KC at 6 db down

at 455 KC . 5 V out 4. 6 uv in
at 5 MC . 5 V out 5. uv in

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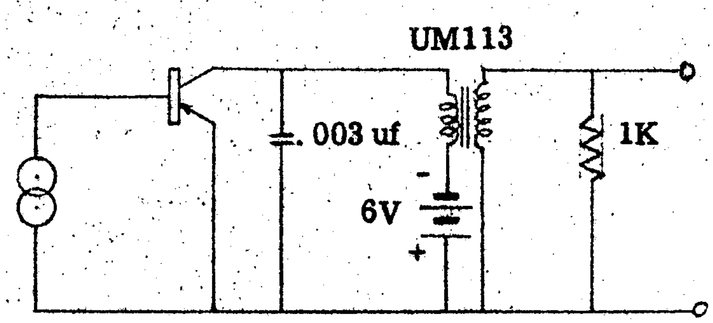
TRANSISTOR COMPARISON CIRCUIT FOR DETECTOR USE



Input 455 kc
Modulation 1000 cps 30%

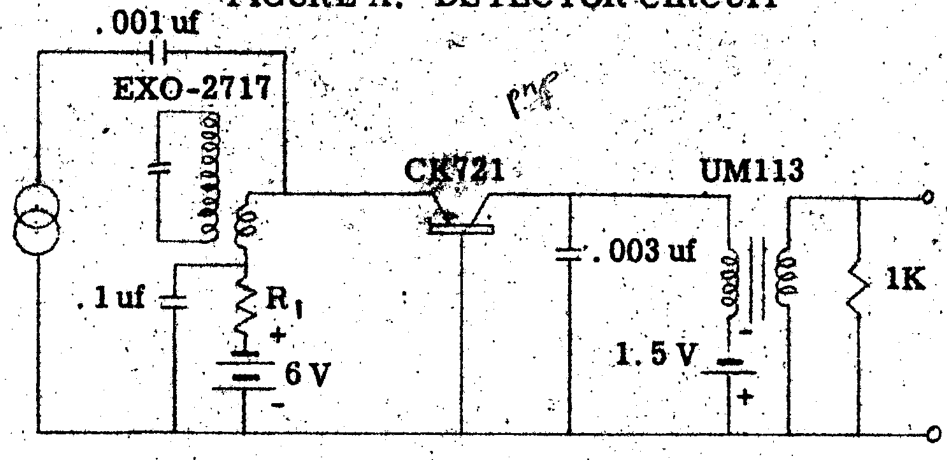
CK762 Transistor

Input	Output	Collector Current
2000 uv	?	15 ua
3000	.00018 v noise	15 ua
5000	.0005 v noise	16 ua
10000	.002 v noise	17 ua
20000	.01 v noise	21 ua
30000	.026 v noise	29 ua

CK721 Transistor

10000 uv	.0003 v noise	4 ua
20000	.0014 v noise	4 ua
30000	.004 v noise	5 ua
60000	.028 v noise	18 ua

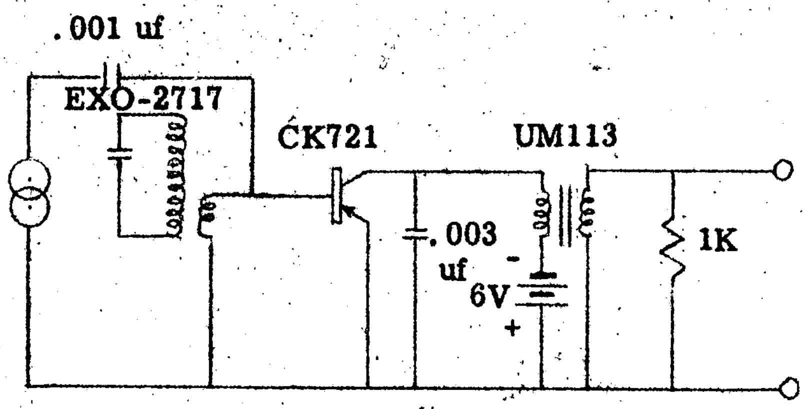
FIGURE A. DETECTOR CIRCUIT



Input 455 KC
Modulation 1000 cps 30%

Input	Output	Collector Current
500 uv	.0001 v noise	40 ua
1000	.0001 v noise	40 ua
2000	.00013 v noise	40 ua
5000	.0005 v noise	40 ua
10000	.0021 v noise	40 ua
20000	.0078 v noise	40 ua

FIGURE B. DETECTOR CIRCUIT



Input 455 kc
Modulation 1000 cps 30%

Input	Output	Collector Current
500 uv	.0001 v noise	8 ua
1000	.0001 v noise	8 ua
2000	.00011 v	8 ua
5000	.00014 v	8 ua
10000	.00042 v	8 ua
20000	.0018 v	8 ua

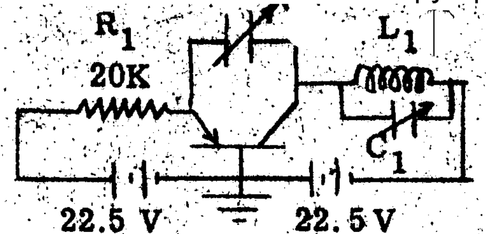


FIGURE 1.

Type CK721
f max approx. 1-1.75 mc
C_2 = 5 - 30 uuf
L_1 = 200 uh
Miller Type 72-73

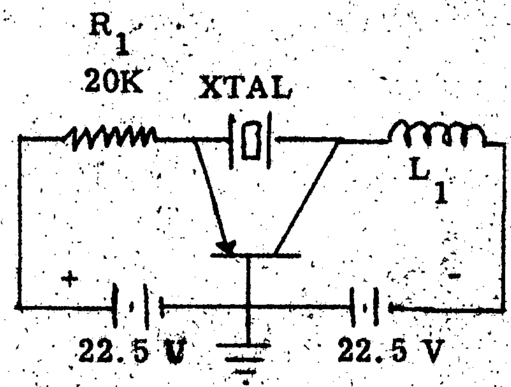


FIGURE 2.

XTAL = 1.25 mc

increase in R_1 raises frequency.

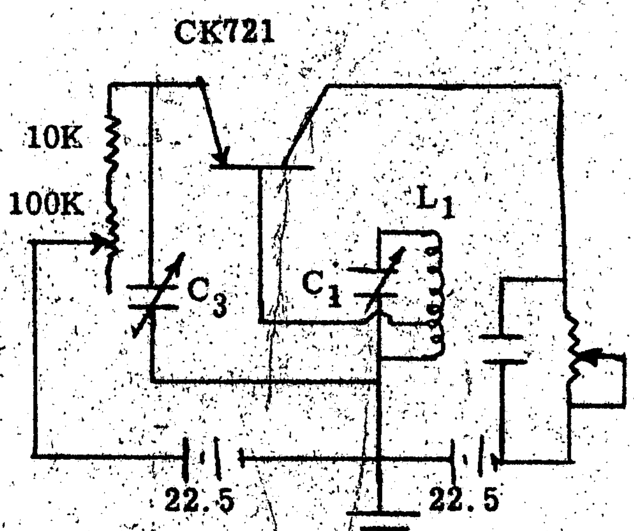


FIGURE 3.

L_1 Same as above

C_1 465 uuf max

C_3 325 uuf max

f max = 1250 KC

f max = 2.15 mc with a specific 721

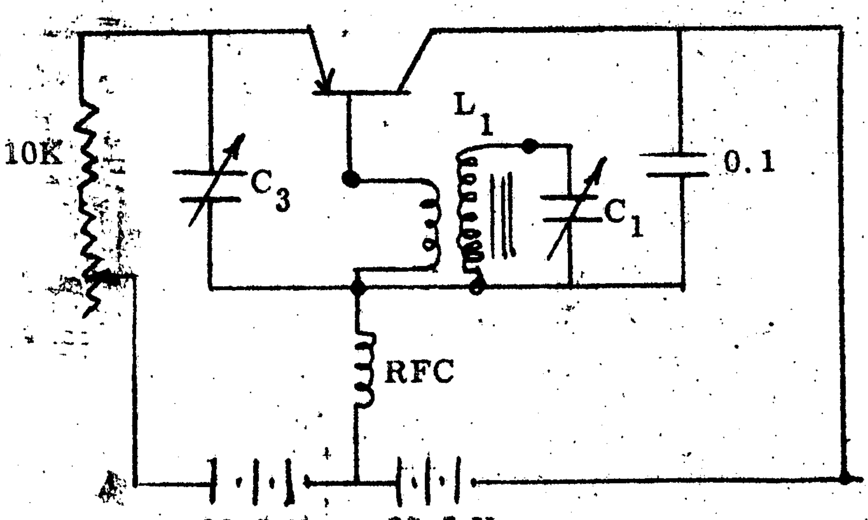


FIGURE 4.

With same specific 721 parts same as Figure 1.

f max = 2.35 mc

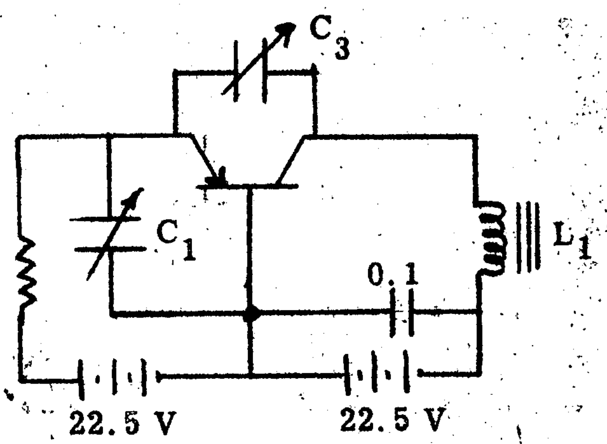


FIGURE 5.

Same CK 721

f max = 2.61 mc

Removal of C_1

f max = 2.8 mc

3 - CK721S tested

all oscillated above 2.0 mc.

Q of L_1 = 20 - 25 at 2 MC

C_Q meter = 110 uuf

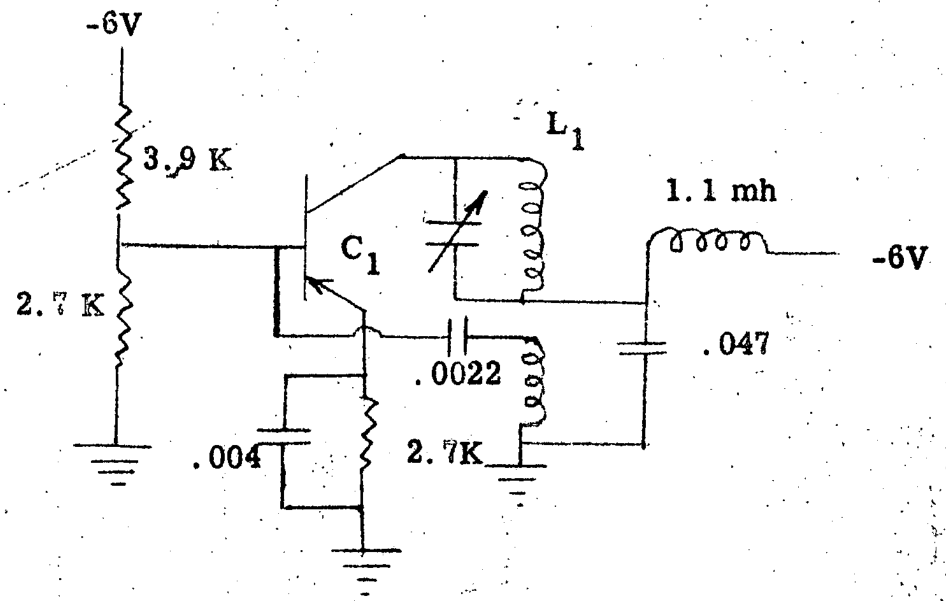


FIGURE 6.

L_1 Same as in Figure 1.

C_1 325 uuf Var.

Max. f = 950 KC

Output low at high end

Took special CK721 to operate

L_1 11 T feedback

111 T secondary

#36 Nylon iron core.

1/8" D 3/8" L.

With 91T Tap at 63 for collector. Q = 44 f = 950 KC

2 other CK721 allow operation to 1200 KC.

OSCILLATORS

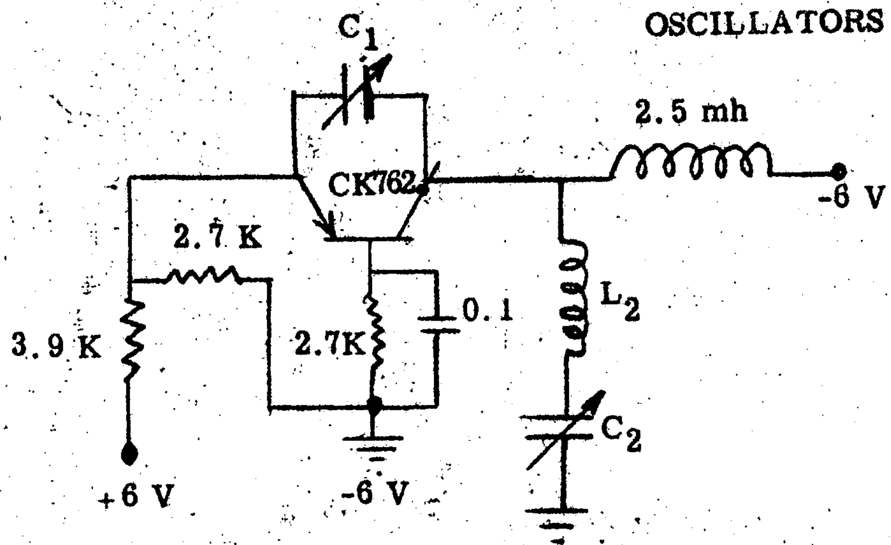


FIGURE 7.

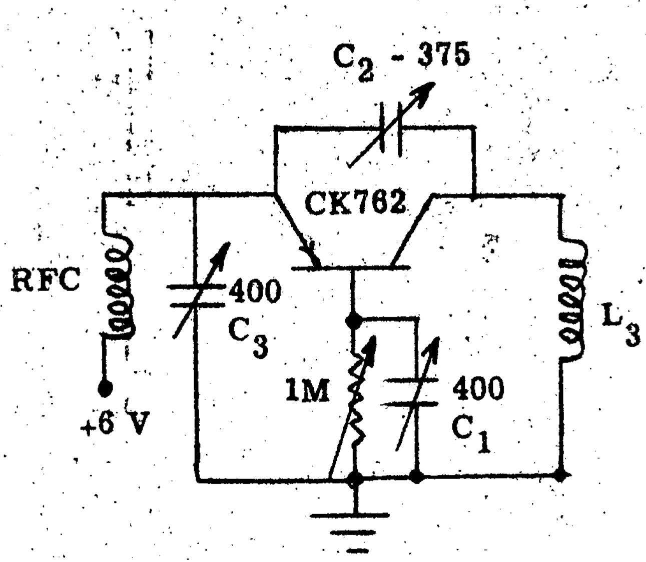


FIGURE 8.

C_1 = 370 uuf max

C_2 = 465 uuf

L_2 = 100T 7-44

3/16 D Form

C_2 shorted → F max 1.2 MC

C_2 = 400 uuf

f max = 1.78 mc

f max limited by coil

f = 8.7 mc

C_2 = 0 uuf

Range restricted by C_1 (squegging)

E_o L_3 = 15 V PP

Smaller L_3

C_2 = min.cap

C_3 = min cap

f = 12.8 mc

CRYSTAL OSCILLATORS

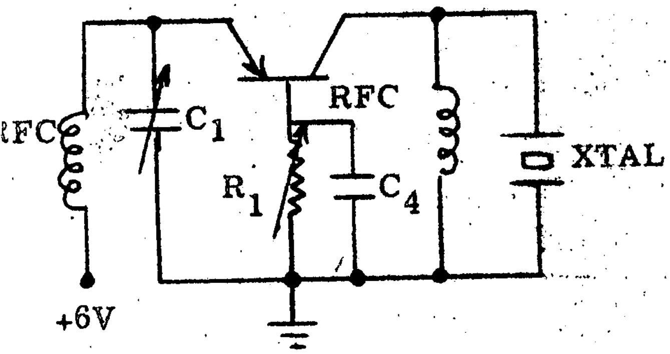


FIGURE 9.

XTAL 1-5 MC or more

R_1 1M

C_1 400 uuf

C_4 .002 uf

RFC - 2.5 mh

e_o (XTAL) = 16 V PP

e_e = 6 V PP

Output from collector may be loaded

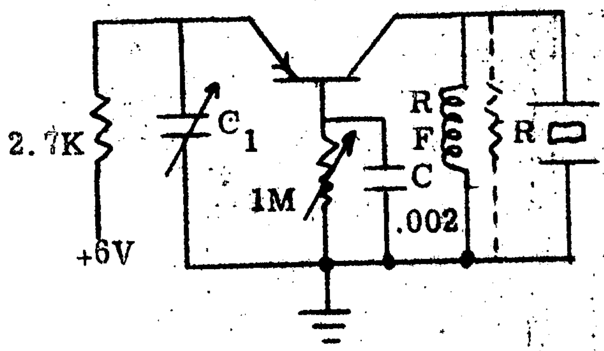


FIGURE 10.

R to reduce possibility of L. F. oscillation - 47K

RFC 500 uh

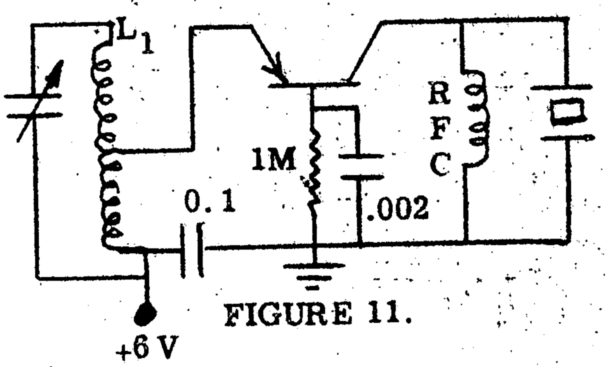


FIGURE 11.

RFC 500 uh

XTAL 5 MC

e_e = 0.7 V

e_{L_1} = 2.2 V

e_c = 0.5 V

I = 0.5 ma

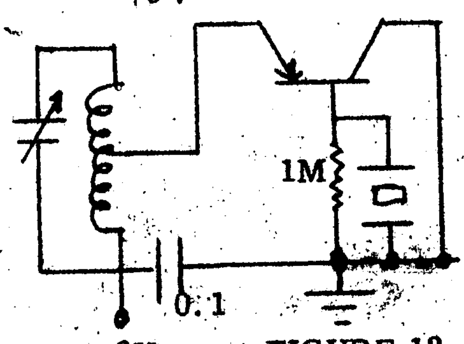


FIGURE 12.

E_o = Same

RECEIVER OSCILLATOR AND MIXER

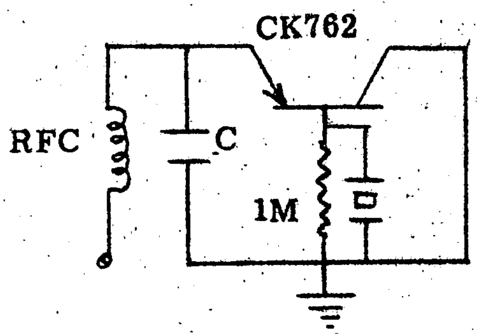


FIGURE 13.

XTAL 3910 KC

RFC 0.5 mh

e_{o_e} = 6.5 V with good regulation

XTALS tried up to 6.4 mc

C - approx. 10-20 uuf may be to load

I_C = 0.5 ma

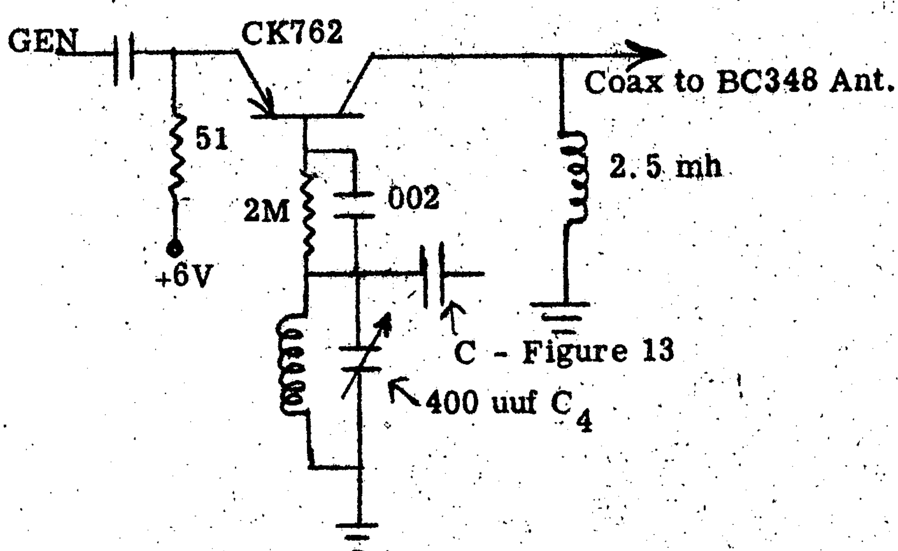


FIGURE 14.

C = 4-30 uuf

BC 348 AVC Read.	Mixer I. F. uv	Conv. at 5.5 mc	Comments
4 V	2.1	8.8 uv	
		5.8	Adj C and C_4
	3.8	5.8	
	6.8	9.0	(45 uv at Receiver)
			(46 uv at Receiver)

MIXER CIRCUITS CK762

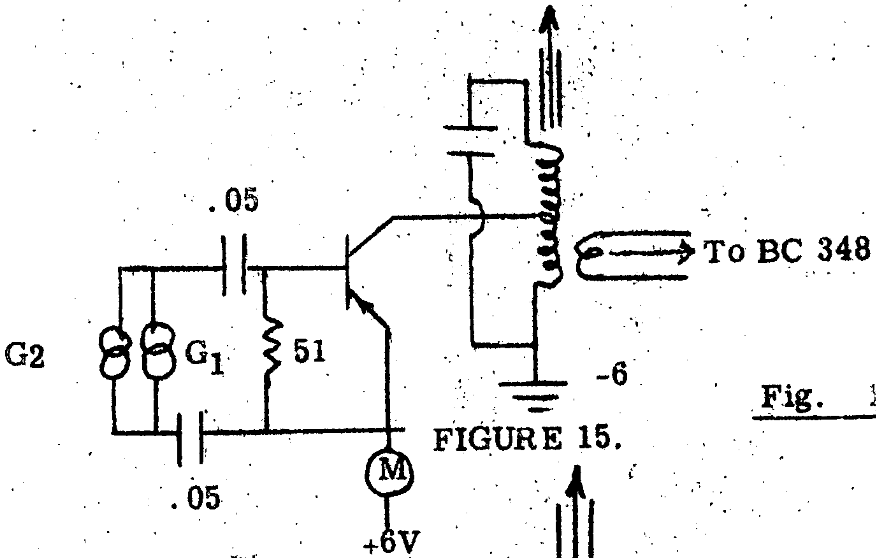


FIGURE 15.

G_1 5 MC - 200 uv

G_2 5.455 MC

I_C = 0.5 ma

Fig.	IF at Mix	AT Rec	5.4 mc
	8.8 uv	38 uv	10.2 uv
	3.6	36 uv	7.3

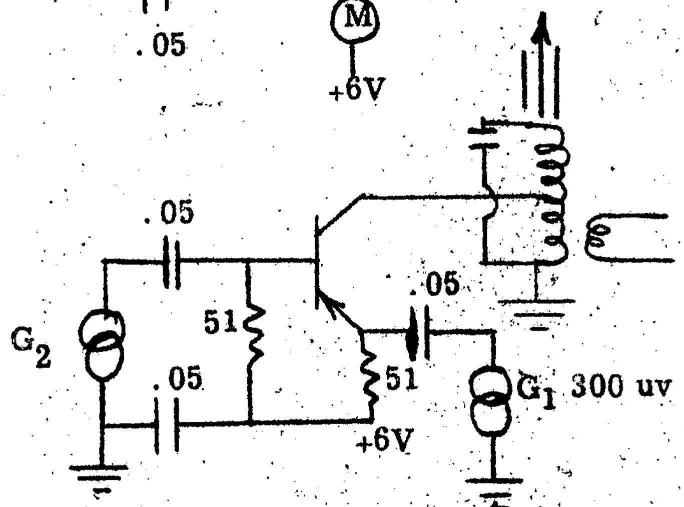
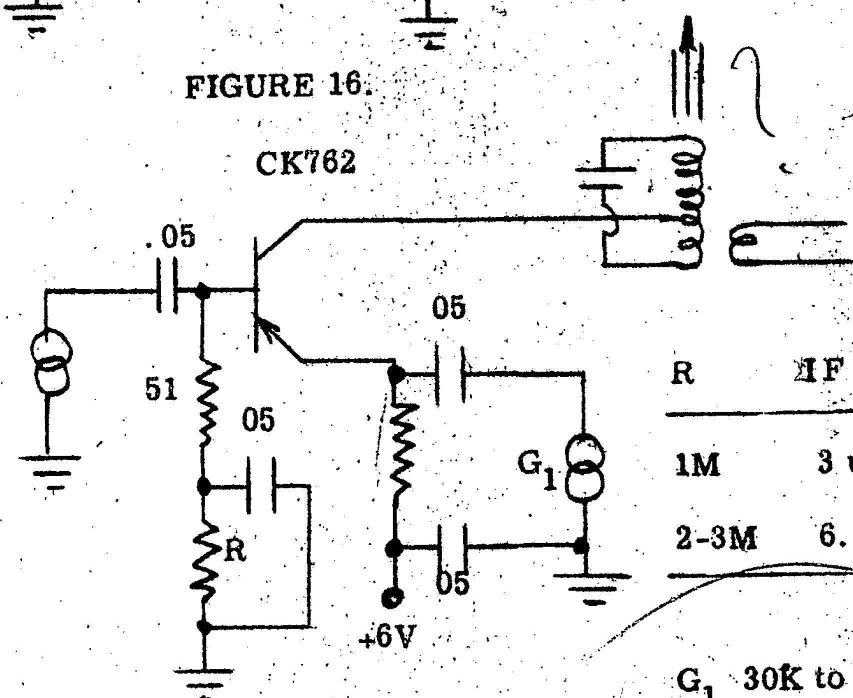


FIGURE 16.

CK762



R	IF at Mix	AT Rec	5 MC	I_C
1M	3 uv	45 uv	11 uv	0.5 ma
2-3M	6.5 uv	45 uv	13 uv	0.25 ma

G_1 30K to 100K uv

FIGURE 17.

TETRODE TYPE RDX302

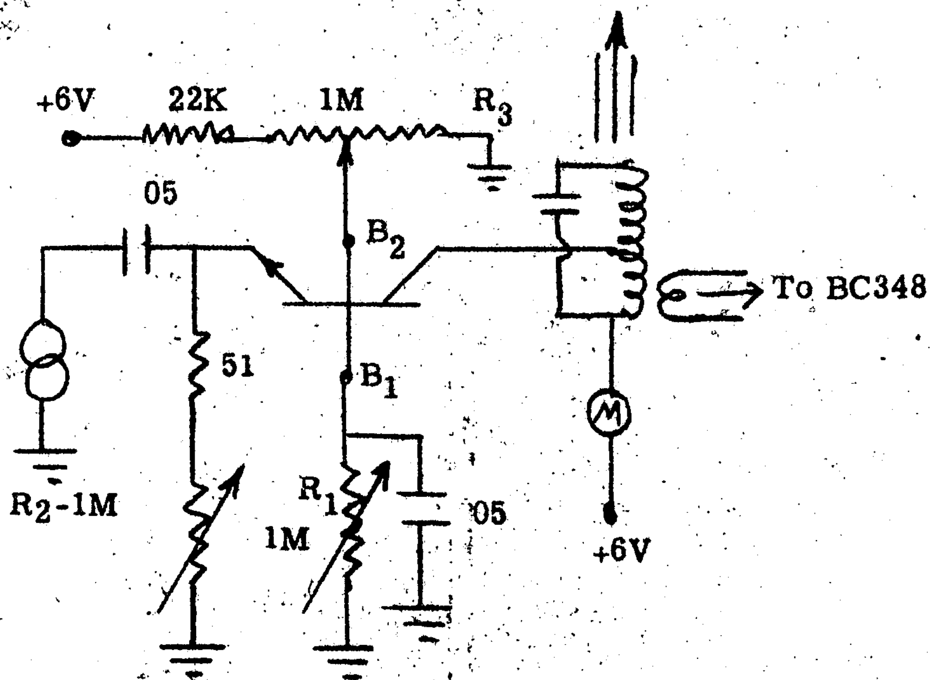


FIGURE 18.

As an Amplifier

1 uv = 4 V AGC on BC348

R_1 any value greater than 0

$R_2 \approx$ 1K

R_3 adj for 0.25 ma

As a mixer

osc in B_2

30 uv = 4 V AGC

Comment - poor mixing

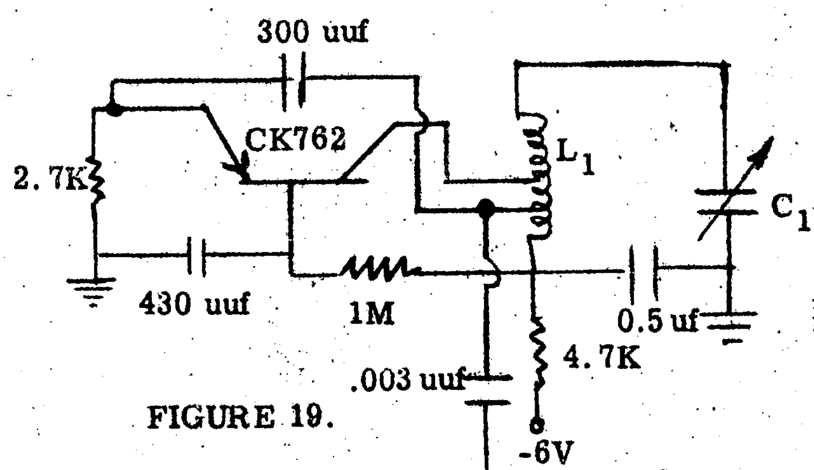


FIGURE 19.

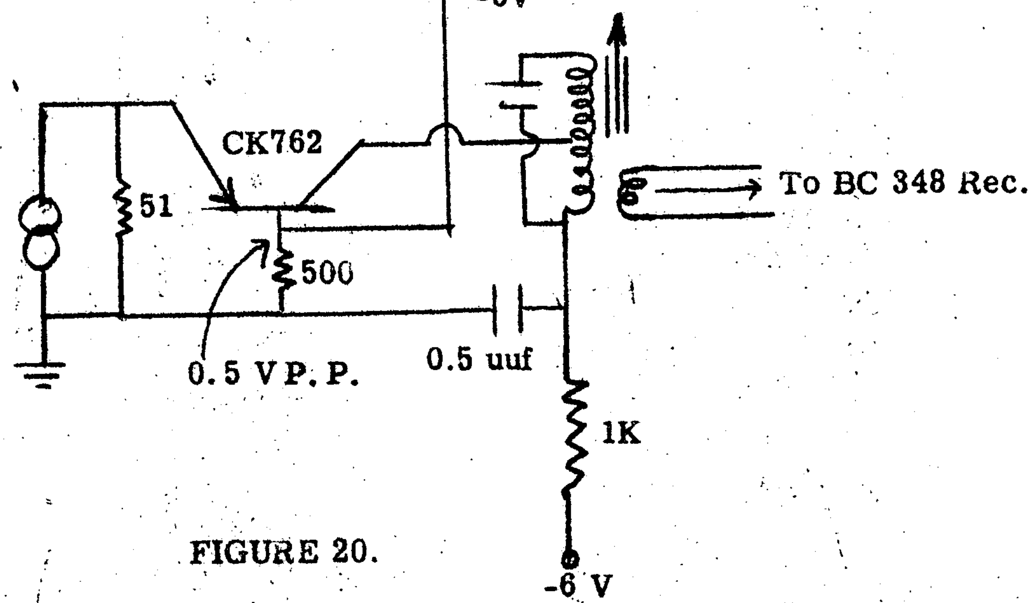


FIGURE 20.

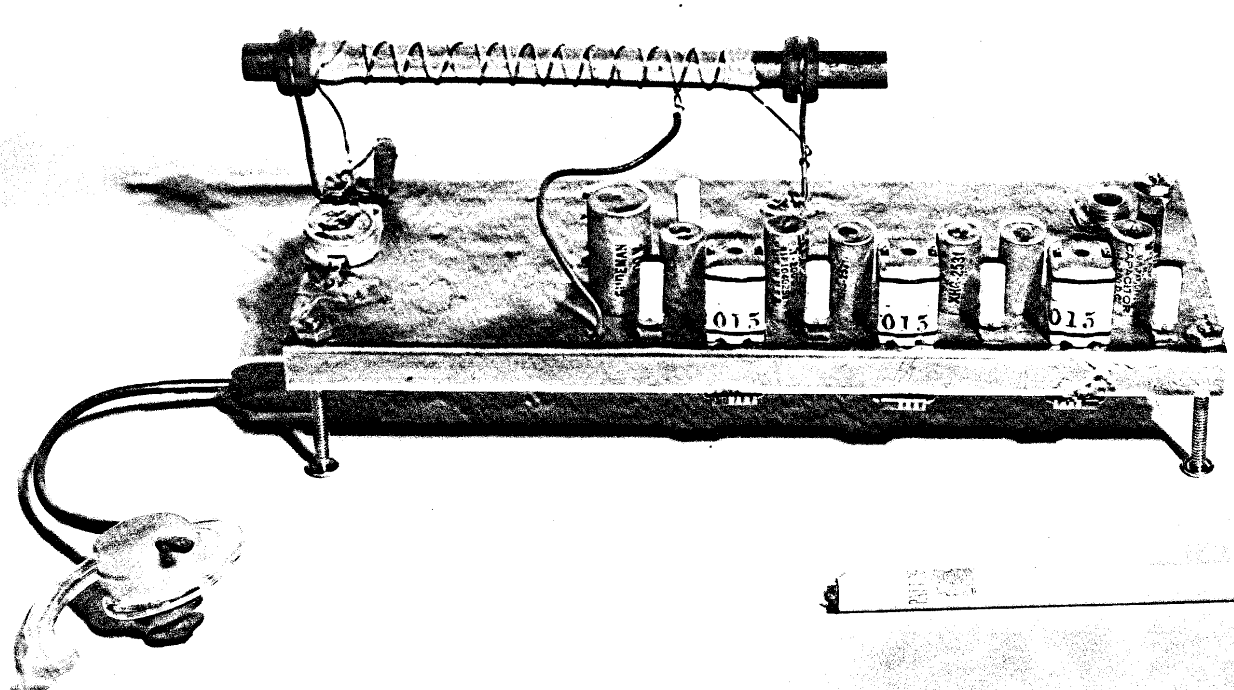
L_1 24T 3/4" D 32T/$_{in}$

e_{tap} 2 1/4 T

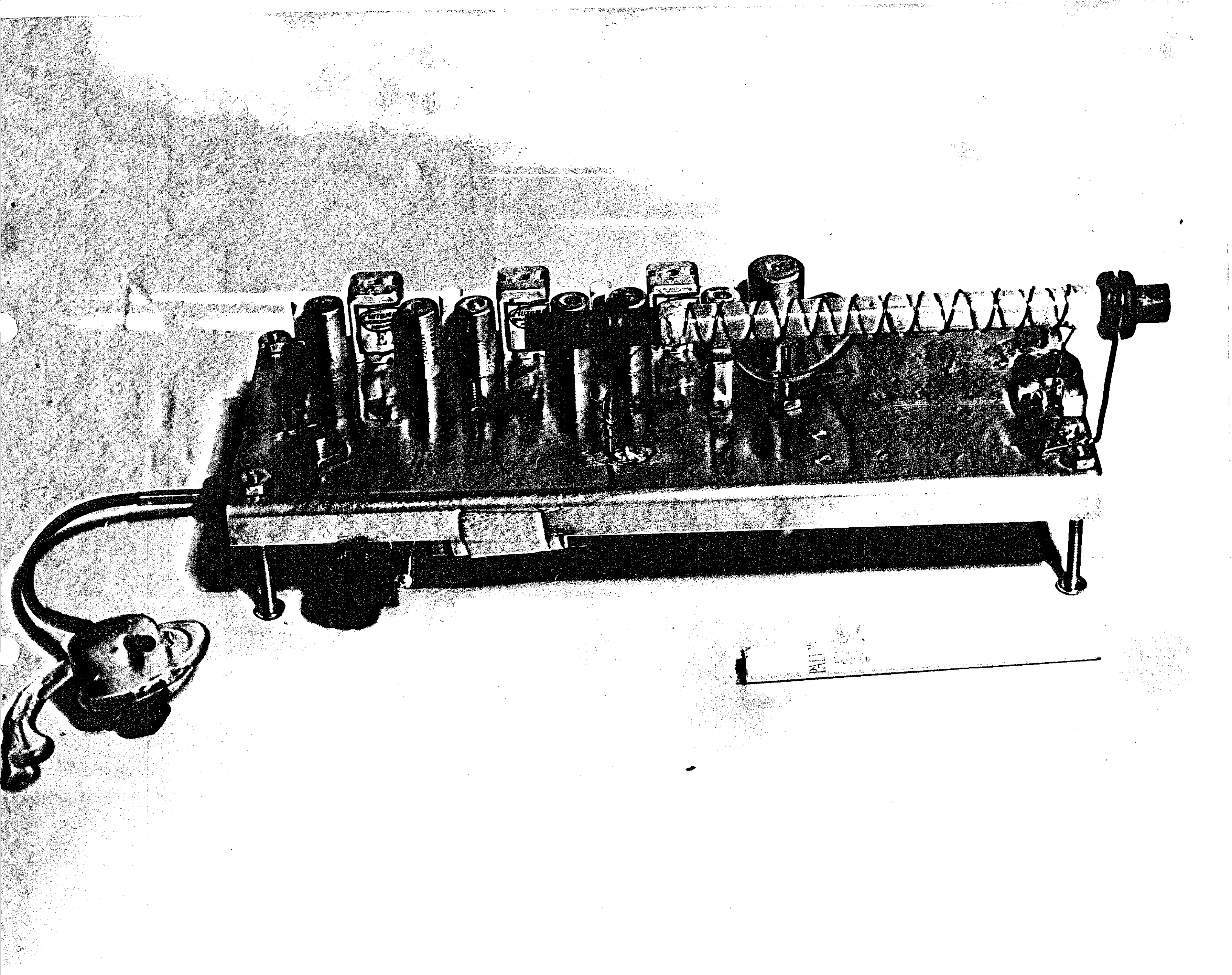
C tap 12 1/4 T

C_1 approx. 158 uuf.

f mixer = 4.6 mc



BREADBOARD RECEIVER OF REPORT #5.



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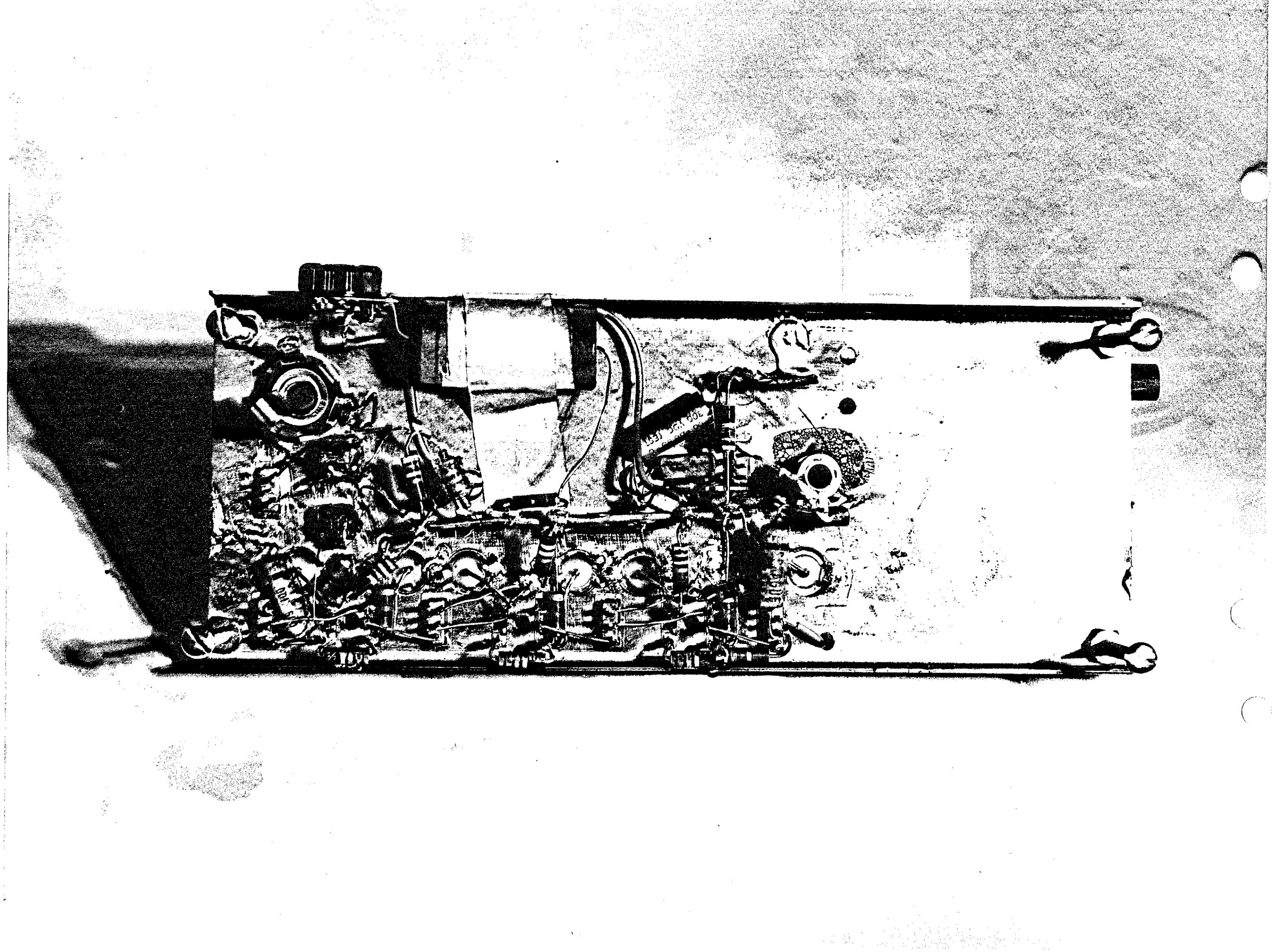
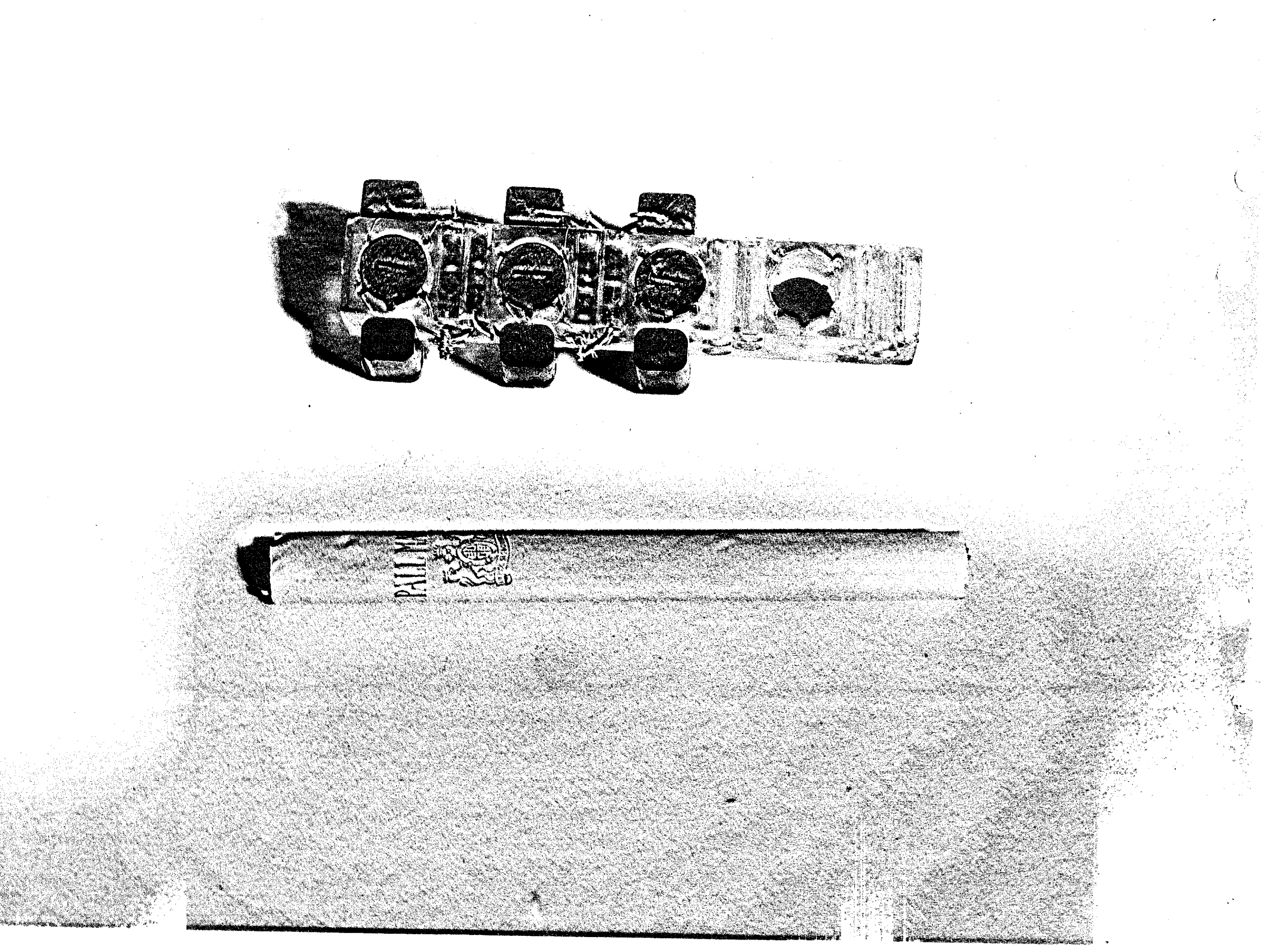
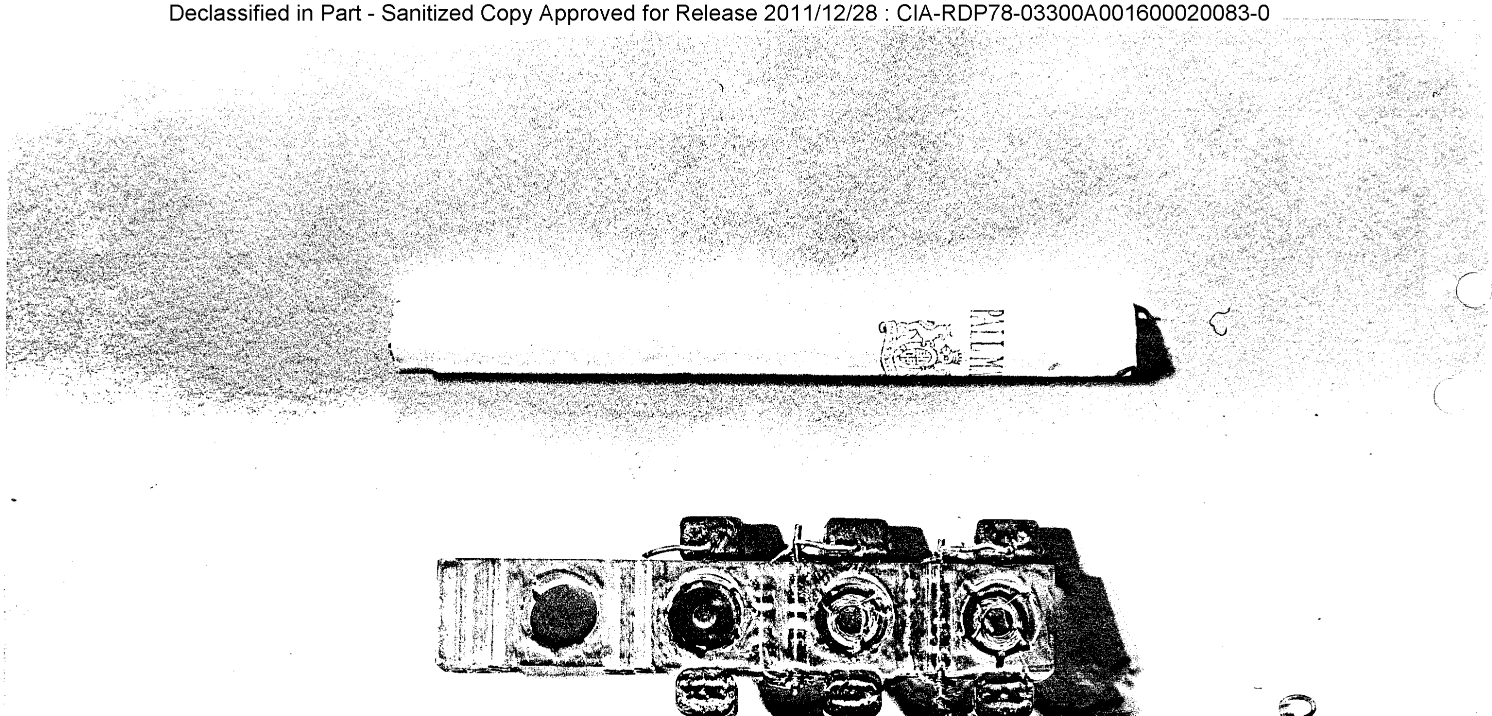


I. F. AMPLIFIER AND OSCILLATOR STRIP - EXPERIMENTAL





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